BENEFIT CONTINUED FROM PAGE 3

link from the 34-GHz uplink signals. This dichroic consists of many rectangular (nearly square) holes cut into a thick plate. The holes are basically short sections of waveguides. Each short waveguide section has two steps that reflect the 32-GHz signal and pass the 34-GHz signal. Construction of this plate consisted of machining three, thick plates with one set of hole sizes, and two, thinner plates with the smaller hole sizes. The dichroic is then assembled by layering each of the plates, as shown in Figure 2. We refer to this type of dichroic as a 5-layer plate. The plate provides the transmission/reflection performance shown in Figure 3. The high power performance of this plate was one of the major results to be characterized in the planned demonstration.

A second consideration in operating a system with multiple frequency (X-band and Ka-band) uplinks, is to isolate the multiple frequency (X-band and Ka-band) downlink systems from both transmitters. The typical diplexer described above splits the uplink from the downlink in the same frequency band. How then to protect the Ka-band receiver from the X-band transmitter and vice versa? Typical DSN systems use maser, low noise amplifiers (LNAs) that inherently have a very narrow bandwidth, and thus provide their own measure of protection from out-of-band interference. However, one of the major goals within the Advanced Technology Program is to develop lower cost, more reliable systems, based on high electron mobility transistors (HEMT) LNA's. The ability to use HEMT LNAs should be proven in the demonstrations of these diplexing systems. An HEMT has inherently very wideband frequency performance. As a result, there must be added filtering to protect against the out-of-band signal from other transmitter sources. For this reason, the Low Noise Amplifier Work Area, which collaborated with this demonstration, provided filters that would be placed in front of the LNAs and that could operate in the cryogenic refrigerator. Between the diplexers and the added front-end filters, the required

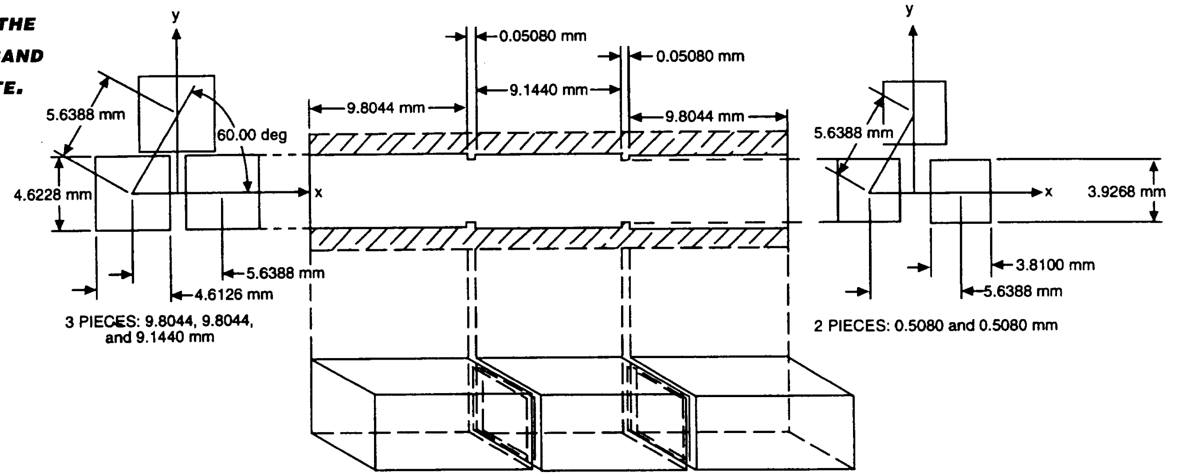

FIGURE 2. LAYOUT OF THE HOLES AND HOLE PATTERN FOR THE 5-LAYER KA-BAND DICHROIC PLATE.

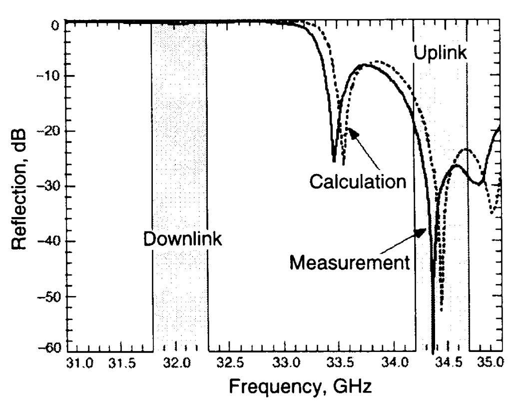

FIGURE 3. REFLECTION/TRANSMISSION PERFORMANCE OF THE 5-LAYER KA-BAND DICHROIC PLATE.

CONTINUED ON PAGE 10

RADIO METRIC TRACKING

A Wide Area Differential GPS (WADGPS) System for NASA Positioning and Navigation Application

Stephen M. Lichten

The Global Positioning System (GPS) is changing the way we do positioning and navigation worldwide. Initially developed by the U.S. Air Force as a military navigation system, GPS now dominates a much broader range of applications, including scientific and commercial ones. The U.S. civilian community, due to economic, societal, and political factors, is gradually assuming a greater role in the control of GPS. It must be remembered, however, that GPS was originally, and still remains, a military satellite system. With 24 satellites circling the globe in 12-hr orbits, GPS provides near total coverage of the world in low-Earth orbit, airflight, ground and sea applications.

Ironically, one of the key features of GPS in its original design was that the most accurate capabilities for user positioning, particularly in real-time, would be reserved for certain military users. This meant that "denial of accuracy," also known as selective availability (SA), would reserve the highest precision positioning applications with GPS for "authorized" users. In the 1980s, however, the Jet Propulsion Laboratory (JPL) and other research centers began to study a capability for precise positioning using GPS. There were several key areas of application developed in the Tracking Systems and Applications Section (335): precise estimation of Earth platform parameters in calibration of deep space tracking observables for what would otherwise be serious systematic errors in deep space navigation; sub-10 cm accuracy for orbit determination of low-Earth orbiters, specifically the Topex/Poseidon satellite; and geodetic studies of crustal motion and plate tectonics. The work at JPL was initially funded through the Deep Space Network (DSN) Technology Program, the Topex Project, and the National Aeronautics and Space Administration (NASA) Geodynamics Program. The GPS effort at JPL, in those early years, included a hardware component for development of state-of-the-art GPS receivers; a software component for development of the most sophisticated and accurate GPS analysis software available (GIPSY-OASIS); and an experimental component, where field measurements were made and GPS data were analyzed.

In the software area, JPL's initial contribution was development of new techniques to enable unprecedented accuracy. A unique achievement for ultraprecise orbit determination of a low-Earth satellite was the estimation of the Topex/Poseidon satellite ephemeris to an accuracy of better than 2 cm in the radial component. These solutions were used for refinement of the Earth's gravity field and eventually became "the benchmark" against which all other solutions for Topex were compared (Topex carried three other systems for orbit determination). Similar results were achieved for GPS orbit determination and precision ground geodesy. JPL is still the world leader in precision GPS estimation techniques.

In the early to mid-1990s, JPL developed automated procedures for analysis of global GPS data sets, in preparation for implementation and operation of the GPS Calibration System for the DSN. This system will be fully operational in FY99 (provisional operations start in FY98) and will eventually reduce the amount of DSN

CONTINUED ON PAGE 6

WADGPS CONTINUED FROM PAGE 5

70-m antenna time to essentially zero for Earth platform calibrations, down from its present 1000 hrs/yr. The "turnaround time" for analyzing a 24-hr GPS global data set was reduced more and more and the automated capabilities became more and more sophisticated. Currently, a 24-hr global GPS data set can be analyzed in several hours: the automated procedures developed both for DSN calibrations as well as for Topex precise orbits were, and still are, dominated simply by the amount of time needed to wait for the data to be released to JPL. The realization set in that if data were retrieved, say, every few hours from the global network, the solutions could be updated more frequently and made available even faster. In fact, it would be possible to process data every few minutes, or even every second, if real-time data links with a few dozen worldwide ground sites could be established.

By the mid-1990s, the GPS team at JPL was beginning to seriously consider a real-time capability for GPS analysis. The following drivers for such a capability were becoming stronger:

- Real-time navigation capability for NASA orbiting platforms. The potential exists for huge cost savings from reduction, if not elimination, of certain ground operations segments currently needed in NASA and other government programs. Applications include routine (coarse accuracy) navigation for virtually any future NASA satellite; formation flying, docking and other proximity operations; precise pointing and scheduling of remote sensing instruments; and real-time SAR imaging and altimetry with significant cost reductions and new real-time navigation capability to vary SAR baselines.
- Real-time onboard generation of science data products in satellite missions. In keeping with the philosophy of the New Millennium and other NASA programs that stress autonomous spacecraft operation and maximal in situ generation of science data products, a very precise real-time orbit determination capability would enable near real-time (or even real-time) downlinks of essential science products from low-Earth orbiters to science investigators and users, products which currently require days or even weeks to generate on the ground with elaborate and expensive processing systems. Such a capability on Topex/Poseidon, for instance, would have delivered global and basin scale oceanography data to the science community 10 times faster than NASA's current operational process at less than one-tenth the current cost of operations.
- Real-time Earth platform parameter calibration products for deep space tracking.
- Technology transfer: JPL was approached repeatedly by the private sector and by other non-NASA government agencies with requests for a real-time GPS capability.

Three significant developments occurred nearly simultaneously in 1996 that catapulted JPL into the real-time GPS world.

(1) After many discussions, Caltech licensed JPL's real-time versions of the previously well established GIPSY-OASIS and GPS ionospheric calibration software to a company (SATLOC) developing a precise real-time positioning capability to serve the high-technology agricultural market.

(2) At this point, NASA Code O (with particularly close involvement from John Rush, NASA Headquarters) was also encouraging JPL to develop a real-time, GPS-based precise positioning capability to support NASA satellite navigation. The NASA system might look like Figure 1. It utilizes a wide area differential GPS (WADGPS) technique to improve accuracy and guarantee reliability and integrity over a wide geographical area. A global network of ground sites (30+) returns global GPS tracking data every second to two control centers,

CONTINUED ON PAGE 7